Flathead sole (*Hippoglossoides elassodon*)*

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Biology

Flathead sole (*Hippoglossoides elassodon*) is a right-eyed flatfish commonly encountered in the eastern Bering Sea (EBS) and the Gulf of Alaska (GOA). Flathead sole is similar in appearance to a less common, closely related species, Bering flounder (*H. robustus*). Despite differences in biology and spatial distribution, *H. elassodon* and *H. robustus* are managed together as a two-species complex in the Bering Sea/Aleutian Islands (BSAI) assessment area where their ranges overlap (Stockhausen et al., 2008).

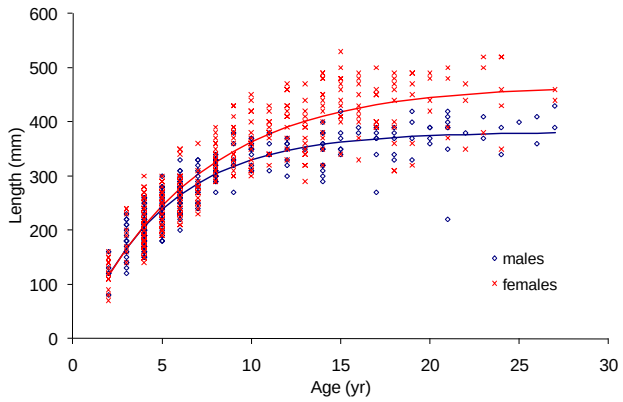

Figure 1
Length-at-age data fit with von Bertalanffy growth functions for male (n=246) and female (n=320) flathead sole collected from a trawl survey in the Bering Sea in 2007.

Flathead sole are typically found on silty or muddy bottoms at depths from shallow nearshore waters to 1050 m, although they most often occur at depths less than 366 m (Mecklenberg et al., 2002). Flathead sole spend the winter along the outer shelf, moving to shallower waters in the spring (Witherell, 2000). Stock biomass in the BSAI increased dramatically during the

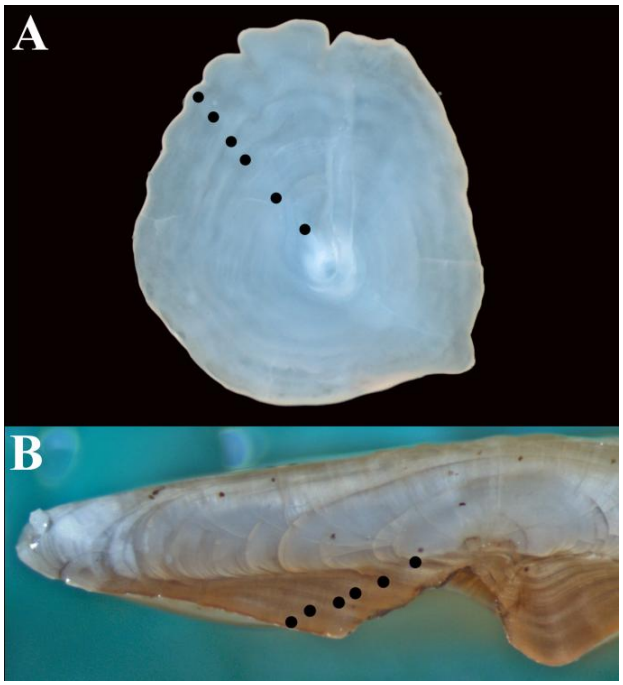

Figure 2
A) Otolith surface pattern, and B) break-and-burn pattern from a 310 mm female flathead sole collected in June 2002. Age estimate is 6 years. Viewed with reflected light.

Table 1

Age and length estimates (minimum, maximum, and average), otolith preparation method (SU: surface; BB: break-and-burn), and precision estimates (Agree: percent agreement; CV: coefficient of variation; APE: average percent error) for flathead sole aged by the AFSC Age and Growth Program. Data shown by region and year collected.

		AGE (yr)			LENGTH (mm)			METHOD (%)		PRECISION (%)		
Year collected	*n*	Min	Max	Ave	Min	Max	Ave	SU	BB	Agree	CV	APE
Bering Sea/Aleutian Islands												
2007	1020	2	31	11	70	530	298	33	67	36	6.9	4.9
2006	1049	1	31	11	50	500	293	32	68	43	6.0	4.2
2005	922	2	29	11	90	500	287	21	79	35	8.3	5.8
2004	971	1	29	11	90	510	308	25	75	41	7.3	5.2
2003	285	2	26	9	100	490	286	34	66	55	6.5	4.6
2002	465	1	25	9	70	530	299	30	70	61	4.3	3.1
2001	1156	2	31	13	100	510	301	5	95	30	9.1	6.5
2000	1026	1	28	13	70	540	311	16	84	35	6.6	4.6
1995	581	2	27	10	120	510	297	1	99	41	6.2	4.4
1994	509	2	24	10	100	500	285	8	92	41	7.7	5.4
1993	136	4	19	10	170	480	340	0	100	44	5.2	3.7
1992	420	2	23	8	100	520	288	5	95	37	7.8	5.5
Gulf of Alaska												
2007	755	1	31	8	60	540	298	18	82	51	6.5	4.6
2005	942	1	26	9	70	520	283	36	64	56	5.9	4.2
2003	499	1	28	8	80	550	304	52	48	67	4.2	3.0
1999	1208	1	24	8	50	530	289	31	69	60	5.7	4.0
1996	548	1	27	8	60	520	282	15	85	52	5.3	3.8
1993	312	1	25	9	70	510	291	16	84	56	5.5	3.9
1990	247	2	33	9	110	490	307	6	94	46	6.2	4.4

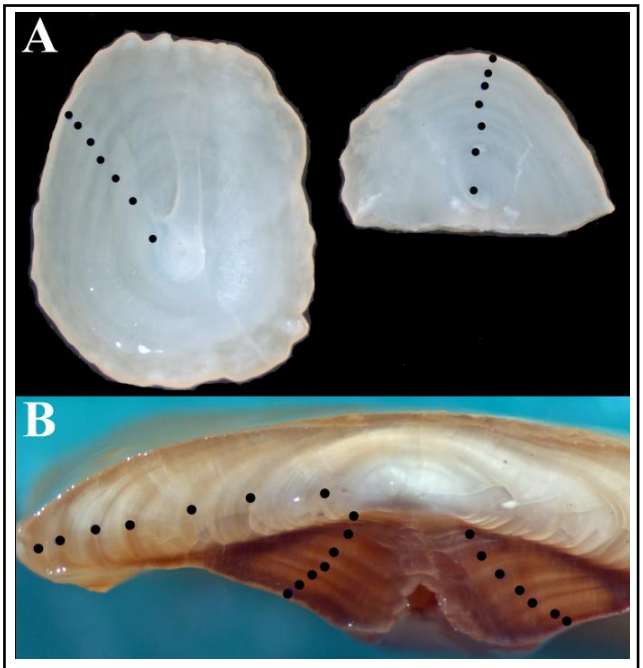

Figure 3

A) Otolith surface pattern, and B) break-and-bake pattern from a 300 mm female flathead sole collected in June 2002. Age estimate is 7 years. Viewed with reflected light.

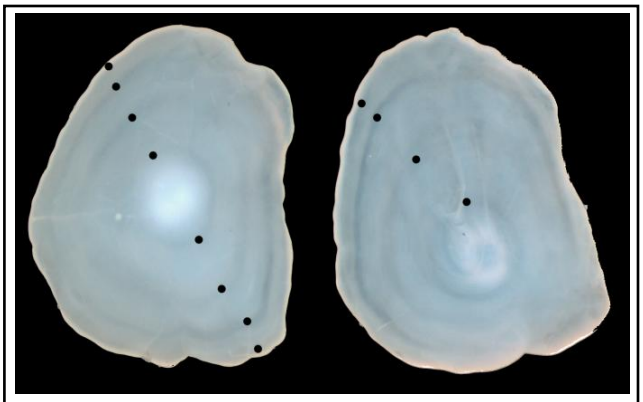

Figure 4

Clear otolith surface patterns from a 190 mm female flathead sole collected in June 2002. Age estimate is 4 years. Viewed with reflected light.

1980s and peaked in the mid-1990s, but has since decreased to a level of around 800,000 metric tons (Stockhausen et al., 2008). There are directed trawl fisheries for flathead sole in the BSAI and the GOA, with fishery recruitment beginning around age-3 (Stockhausen et al., 2007; Stockhausen et al., 2008). Flathead sole

are also caught incidentally in target fisheries for Pacific cod (*Gadus macrocephalus*), walleye pollock (*Theragra chalcogramma*), and other flatfish (Stockhausen et al., 2007; Stockhausen et al., 2008).

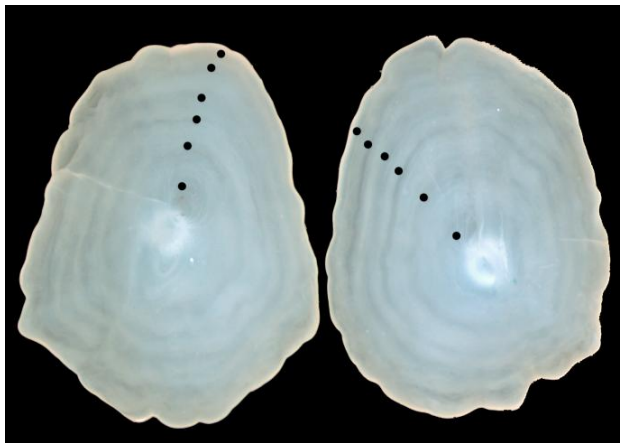

Figure 5
Otolith surface patterns from a 270 mm female flathead sole collected in June 2002. Age estimate is 6 years. Viewed with reflected light.

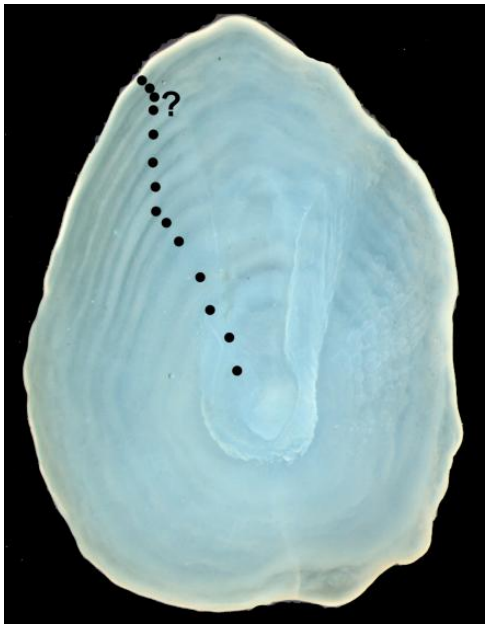

Figure 6
Relatively clear otolith surface pattern from a 380 mm female flathead sole collected in June 2002. Looking at the surface pattern alone, it is not clear whether the 11th translucent growth zone (indicated by "**?**") consists of one or two annual marks, resulting in an age estimate of 14 or 15 years. Subsequent examination of the break-and-burn pattern (not shown) resulted in a final age estimate of 15 years. Viewed with reflected light.

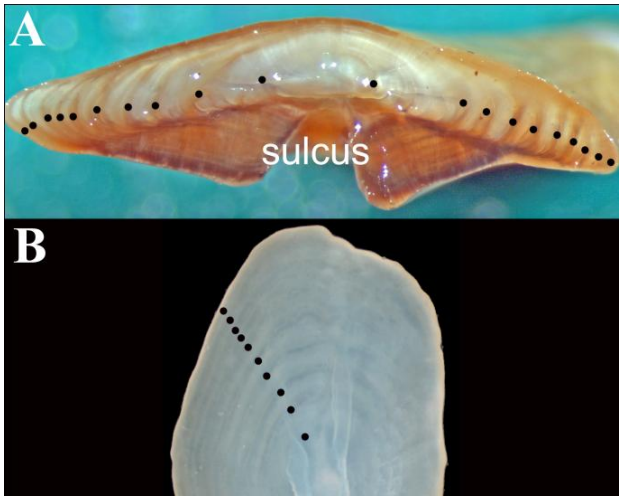

Figure 7
A) Otolith break-and-burn cross section from a 310 mm female flathead sole. Dorsal and ventral tips are clearer than sulcus region. B) Otolith surface pattern confirms break-and-burn age estimate of 10 years. Viewed with reflected light.

Flathead sole are spring batch spawners (Stark, 2004). In the GOA, spawning begins in April and peaks in May or June (Stark, 2004; Porter, 2005). Females attain 50% maturity around 320-330 mm, or 8.7-9.7 years (Stark, 2004). Females reach a larger maximum size than males (Fig. 1). Von Bertalanffy growth parameters for flathead sole collected during an eastern Bering Sea trawl survey in 2007 were L_{∞}=381.08 mm, k=0.20/yr, and t_0=0.19 yr for males and L_{∞}=467.80 mm, k=0.15/yr, and t_0=0.09 yr for females (Fig. 1). Males grow faster in the EBS than in the GOA, although females exhibit no such regional differences in growth (Stark, 2004).

Age determination history

From 1985 to 2008, the Alaska Fisheries Science Center (AFSC) has collected and determined ages from over 13,000 flathead sole otoliths. Age estimates range from 0 (young-of-year) to 33 years (Table 1). Flathead sole age determination is fairly difficult, with an average inter-reader CV of 7% and percent agreement of approximately 42% (Table 1).

The surfaces of flathead sole otoliths tend to be cloudy, and therefore surface examination is the primary age determination method only for relatively young or clear otoliths. The break-and-

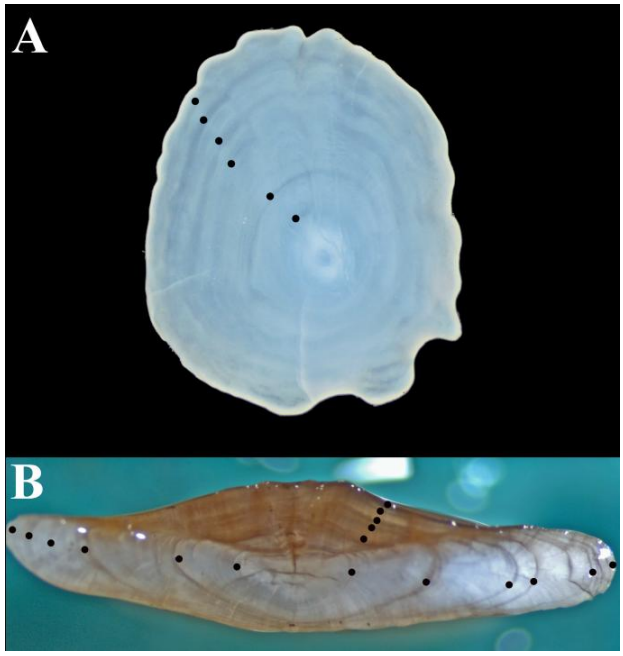

Figure 8
A) Otolith surface pattern, and B) break-and-burn pattern from a 290 mm female flathead sole collected in June 2002. Spacing between third and fourth annual marks is relatively narrow, especially apparent on otolith cross section. Age estimate is 6 years. Viewed with reflected light.

burn technique was favored until the break-and-bake method was introduced in 2003. Baking is now generally the preferred method for flathead sole otoliths because it usually produces more even contrast between translucent and opaque growth zones than burning. However, for some otoliths, the break-and-burn method may result in clearer growth patterns. It is up to the discretion of the age reader as to which method is chosen, although it is often helpful to periodically test both methods on either half of the same otolith. (Please see Goetz et al., 2012 for a more detailed description of standard AFSC otolith preparation methods.)

Current age determination methods

Flathead sole otoliths are relatively difficult to interpret, with growth patterns comparable to those of rex sole (*Glyptocephalus zachirus*).

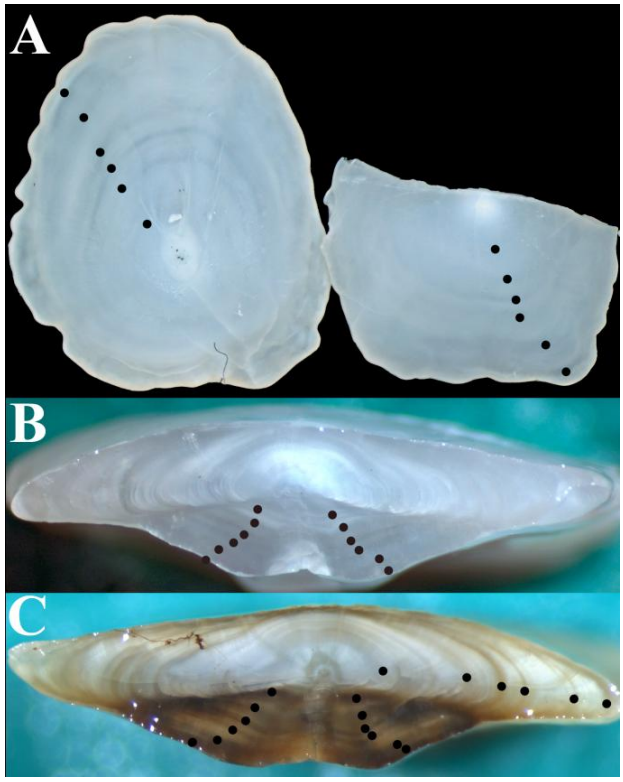

Figure 9
A) Otolith surface, B) unburned cross section, and C) break-and-burn patterns from a 260 mm female flathead sole. The second, third, and fourth annual marks are closely spaced. Age estimate is 6 years. Viewed with reflected light.

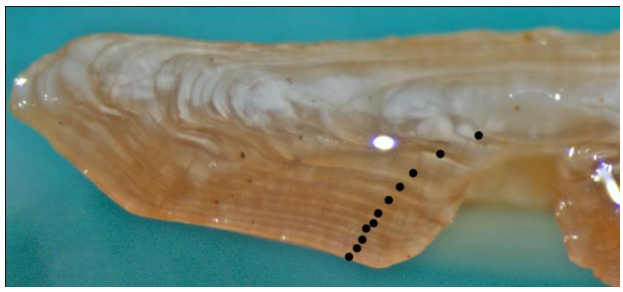

Figure 10
Otolith break-and-burn pattern from a 380 mm female flathead sole. Vague first annual mark. Age estimate is 11 years. Viewed with reflected light.

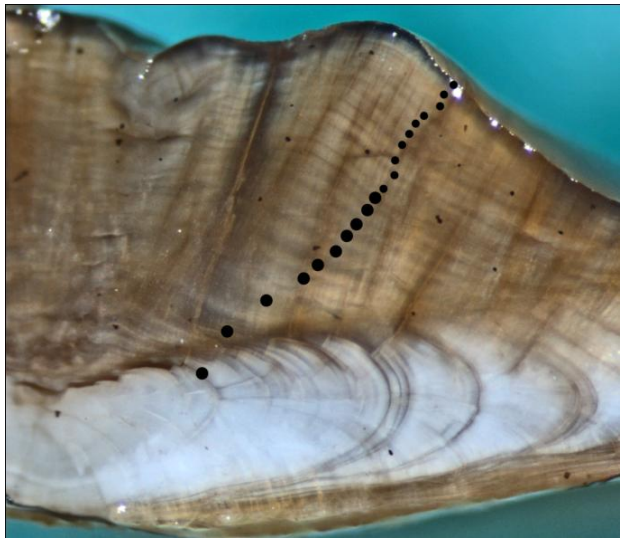

Figure 11
Break-and-burn otolith pattern from a 440 mm female flathead sole. Age reader and tester agreed on an age estimate of 20 years. Specimen captured 13 June 2002. Viewed with reflected light.

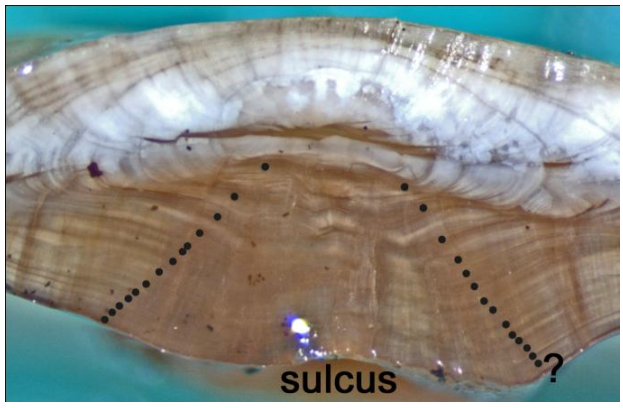

Figure 12
Difficult flathead sole otolith pattern. Collected from a 370 mm female on 30 June 2002. Age estimate from left side of sulcus is 14 years, but could be interpreted as 15 years on the right side because of opaque growth at the otolith margin (indicated by "**?**"). Irregular spacing and faint translucent growth zones further add to the difficulty of this specimen. Viewed with reflected light.

Generally, it is best to closely examine the surface pattern of the eyed-side otolith first and then compare it to either the break-and-burn pattern (Fig. 2) or the break-and-bake pattern (Fig. 3). When clear, the surface pattern is generally reliable up to about 8 years old (Figs. 4, 5), although clear surface patterns are observed in older fish as well (Fig. 6).

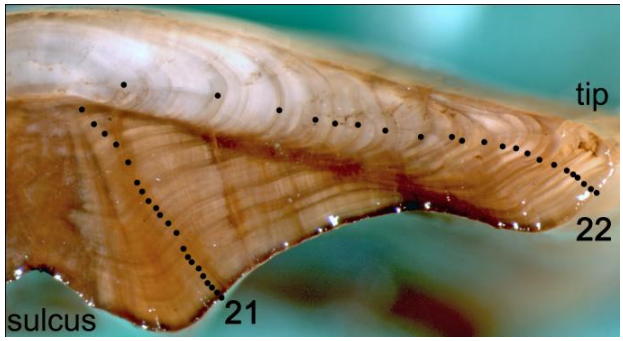

Figure 13
Otolith break-and-burn cross section from a 440 mm flathead sole collected 20 June 2007. Age estimates differ between reading axes: tip=22 years; right side of sulcus=21 years. A final age estimate of 22 years was assigned due to apparent compression of annual marks near the sulcus. Viewed with reflected light.

In flathead sole otolith cross sections, the areas on either side of the sulcus are generally the preferred reading axes. However, in some instances the dorsal and ventral tips may be clearer than the sulcus (Fig. 7). Whenever possible, the age reader should attempt to follow each translucent growth zone from the sulcus to either the dorsal or ventral tip. A translucent growth zone that can be followed around the circumference of an otolith is much less likely to be a check, especially if it is strong.

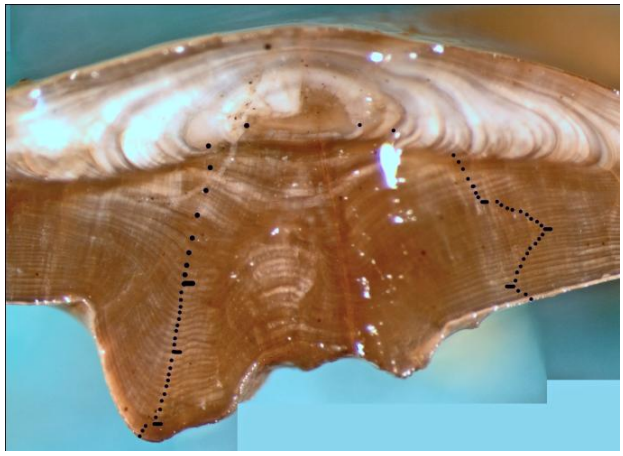

Figure 14
Composite image of the oldest flathead sole aged by the AFSC Age and Growth Program to date. This specimen, a 380 mm male, was assigned a final age estimate of 33 years. Viewed with reflected light.

Occasionally, some opaque growth zones may be relatively wide or narrow compared to

other opaque zones within the same otolith. In these cases, the comparison of surface and break-and-bake patterns is especially useful in distinguishing between checks and annual marks (Fig. 8). The unburned cross section may also be helpful for comparison, particularly in younger fish (Fig. 9).

Another problem typical of flathead sole age estimation is identification of the first annual mark (Fig. 10). Again, viewing the surface pattern in combination with the baked pattern is often necessary to arrive at a final age estimate. Additional examples of flathead sole otolith growth pattern interpretation are shown in Figures 11 through 14.

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